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IRD

OPERATION & MAINTENANCE MANUAL

MODEL 601
Vibration Analyzer

Operation Manual

MODEL 601

Vibration Analyzer

IRD MECHANALYSIS, INC.

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When ordering parts or requesting information,
always refer to Vibration Analyzer and pickup serial numbers.

Vibration Analyzer Serial No. _____

Pickup Serial No. _____

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IRD

MODEL 601

Vibration Analyzer

INTRODUCTION

The IRD Model 601 Vibration Analyzer is a rugged, accurate and reliable electronic instrument designed to perform three important functions relating to the detection, measurement, analysis, and correction of mechanical vibrations.

1. Detect and measure the amplitude and frequency of mechanical vibrations in a great variety of machines.
2. Analyze the measured vibrations - which yield important information relating to the cause or causes of the vibration.
3. Correct unbalance, dynamically, either in-place or in conjunction with a balancing machine.

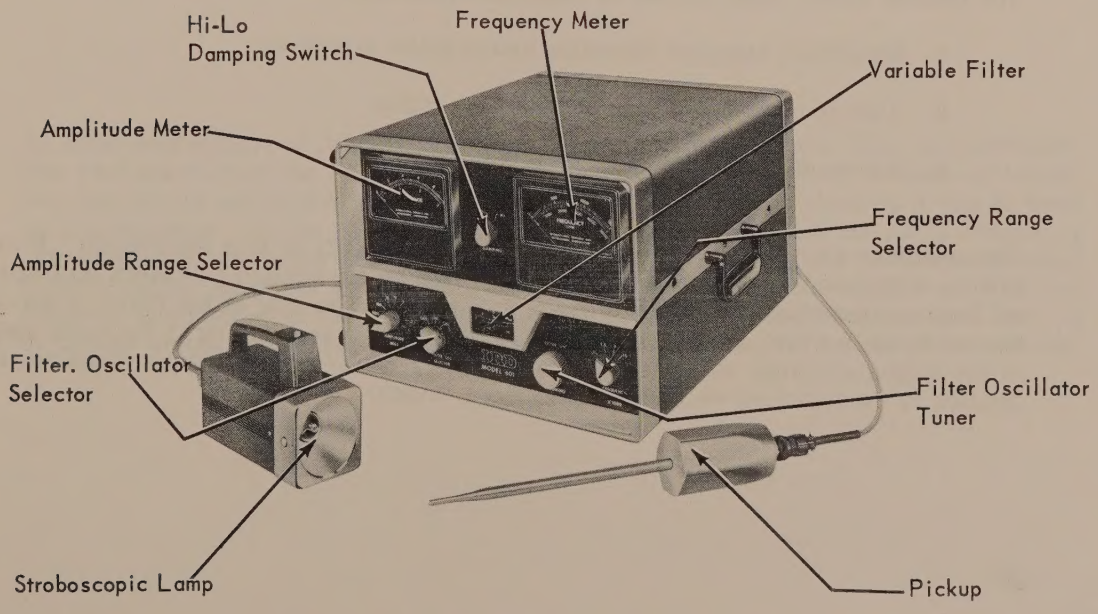


FIGURE 1 - MODEL 601

DESCRIPTION

The Model 601 is specifically designed for use in the low frequency range (150 to 500 cycles per minute) but may be used at any speed up to 15,000 cycles per minute.

The Model 601 derives its advantages from the use of large, easy-to-read panel meters, convenient meter scale ranges, a rugged vibration pickup, ruggedized vacuum tubes and printed circuit boards.

The Model 601 is completely self contained and portable. A compartment is provided for convenient storage of the pickup, probe, strob light and cables. Summarily, this instrument provides versatility, sensitivity and simplicity of operation wherever vibration problems must be solved through vibration analysis and balancing procedures.

The Model 601 provides the means for the rapid measurement of the three parameters required to completely analyze all forms of mechanical vibrations. In cases where corrective measures may be taken to eliminate or control undesirable unbalance forces in a machine, the Model 601 provides a convenient method for balancing.

The parameters needed to perform vibration analysis are: displacement, frequency and relative phase. The Model 601 consists of a vibration pickup, a direct reading displacement meter, a direct reading frequency meter, and a stroboscopic lamp. An electronic variable tuned filter is incorporated in the instrument and provides an extremely useful analysis tool.

The variable filter is extremely useful because mechanical vibration is nearly always complex - the resultant of number of superimposed vibrations of different amplitudes and frequencies and originating from different sources. The filter allows us to measure the amplitude and frequency of each vibration component present and from this analysis we can trace the most serious vibrations to the source and the necessary remedial action can be taken. When balancing operations must be accomplished, use of the filter will permit balancing to extremely fine tolerance.

The tunable filter, then, has three important functions;

1. Simplifies complex vibration and balance problems
2. Aids in pinpointing the source of vibration
3. Allows extremely fine balance tolerance

The continuously variable filter broadens the versatility of this instrument. It simplifies complex vibration and balance problems on assembled machines by filtering all frequencies other than that to which it is tuned. The dial of the filter is divided: the top scale is white, and the lower scale is yellow, corresponding to the color coding of the frequency range selector and the frequency meter (the frequency range selector applies to the filter as well as the frequency meter).

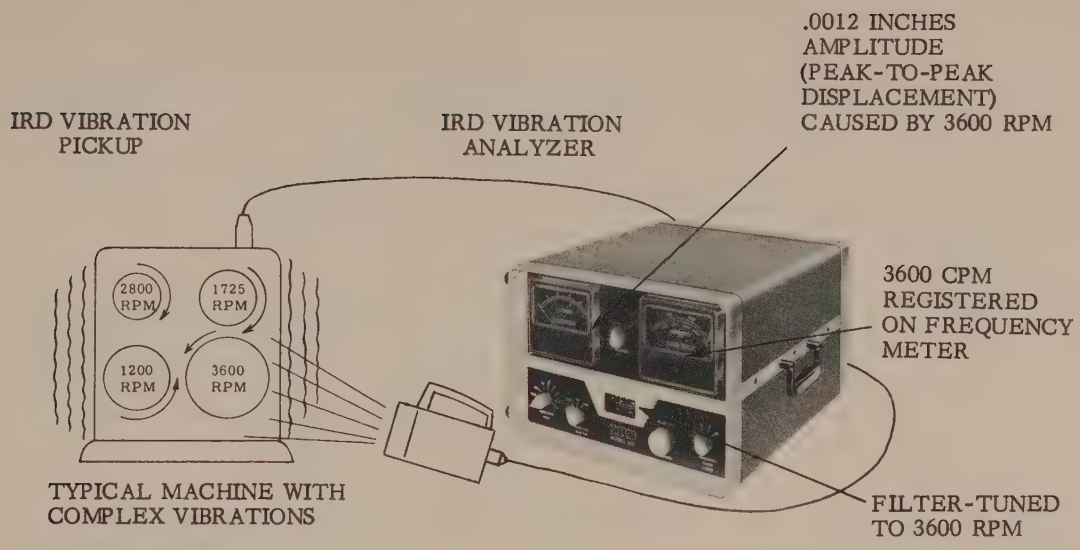


FIGURE 2 - Illustration showing how variable filter is tuned to one component only.

An important feature of this instrument is the method by which the filter may be tuned. The OSC position of the FILTER-OSC selector switch connects a tunable oscillator into the circuit which provides a trigger voltage that fires the strob so it can be used as a tachometer. In the FILTER position of the selector switch the same frequency determining components are used to tune the filter, thus the filter is precisely tuned to the rotating speed of a part when the part is "frozen" by the oscillator, then the selector is switched to the FILTER position. Another method of tuning the filter is by means of tuning the filter knob for maximum response on the Amplitude Meter.

The principle controls for the Model 601 are shown in Figure 1 and their function explained in the accompanying Table 1-1

TABLE 1-1 MODEL 601 CONTROL FUNCTIONS

Schematic Reference Designation	Control Name	Function & Use
S1A, B	Amplitude Range Selector	On-Off switch, test position and Range Selector switch for obtaining amplitude meter reading. Scale corresponds to full-scale amplitude readings for peak-to-peak displacement measurements. Seven positions provide ranges of 100, 30, 10, 3, 1, .3 and .1 mil. (1 mil = .001 inch) full scale meter readings.
S2A, B	Filter - Osc Selector	OUT position permits broadband vibration indication and analysis without filtering. BROAD and SHARP positions introduce the variable frequency filter to permit narrow band filter operation as described on page 11, Item 5. OSC position connects a tunable oscillator into the circuit which provides a trigger voltage so that the strob can be used as a tachometer.
	Tuning Dial	Indicates the frequency to which the variable filter or variable oscillator is tuned.
	Filter - Osc Tuning Knob	Rotates a three-ganged potentiometer which is an integral part of the tuning mechanism to change filter or oscillator tuned frequency.
S3A,B,C,D	Frequency Range Selector	Serves as frequency range selector for the frequency meter, the variable filter and the variable oscillator.
	Damping LO-HI Switch	Provides two degrees of damping for the meters. Eliminates needle fluctuation at low frequencies.
	Amplitude Meter	Amplitude meter indicates peak-to-peak displacement in Mils. Reads: 0 to 3 or 0 to 1 full scale units.
	Frequency Meter	Dual scale meter for reading frequency. Upper scale is white and lower scale is yellow to correspond to color positions on Frequency Range Selector.

The electrically-damped vibration pickup (inductive velocity type, IRD Model 544) is a rugged unit designed to withstand the rigors of industrial usage without impairment to calibration or sensitivity. The pickup responds only to vibration in the direction of the probe (transverse response is less than 5% below 1000 cps). A 12 foot pickup cable is provided with each unit (longer lengths are available). A detachable extension probe is also provided with the pickup.

The general specifications of the Model 601 are:

Amplitude Range: 0 - 100 Mils peak-to-peak displacement with ranges as follows:

RANGE	READS
100	= 0 to 100 mils full scale
30	= 0 to 30 mils full scale
10	= 0 to 10 mils full scale
3	= 0 to 3 mils full scale
1	= 0 to 1 mil full scale
.3	= 0 to .3 mil full scale
.1	= 0 to .1 mil full scale

Frequency Meter Range: 0 to 15000 cycles per minute covered in four ranges as follows:

.5	= 150 to 500 cycles per minute
1.5	= 450 to 1,500 cycles per minute
5	= 1,500 to 5,000 cycles per minute
15	= 4,500 to 15,000 cycles per minute

Filter Range: 150 to 15000 cycles per minute covered in four ranges and tunable over the following bands:

.5	= 0 to 500 cycles per minute
1.5	= 0 to 1,500 cycles per minute
5	= 0 to 5,000 cycles per minute
15	= 0 to 15,000 cycles per minute

Power Requirements: 105 to 130 Volts, 50/60 Cycles, 2 or 3 Wire, 75 Watts

Accessories: Vibration pickup IRD Model 544 inductive-velocity type with extension probe - stroboscopic light - connecting cables.

Overall Dimensions: 10 1/2" x 15" x 18 1/2"

Weight: 37 lbs.

The specifications of the vibration pickup are:

Dimensions:

2-3/16" diameter by 4-5/8" length (including connector)

Thread Size:	1/4-28 x 1/4 N. F.
Weight:	21 ounces
Temperature Range:	Minus 40 F. to 250 F. case temperature
Sensitivity:	240 millivolts RMS ± 10% for .001" peak-to-peak displacement @ 100 CPS corresponding to a velocity constant of 1.08 volts peak per inch per second. Sensitivity is unaffected by orientation.

Longer pickup cables in 25 ft., 50 ft., 75 ft., and 100 ft. lengths are available.

The stroboscopic lamp is housed in a flashlight-type case. A push button switch is incorporated on the case to actuate the stroboscopic bulb (IRD type 1383) may be replaced by unscrewing the shield at the front of the case. Although the stroboscopic lamp is normally triggered by the vibration (for purposes of measuring relative phase of vibration caused by unbalance in a rotating component, and for locating the cause of vibration), it can also be manually controlled through a range of 150 to 5000 flashes per minute. The controls used for the filter are also used for manual strob control, and the .5, 1.5 and 5. ranges are used to indicate the flash rate.

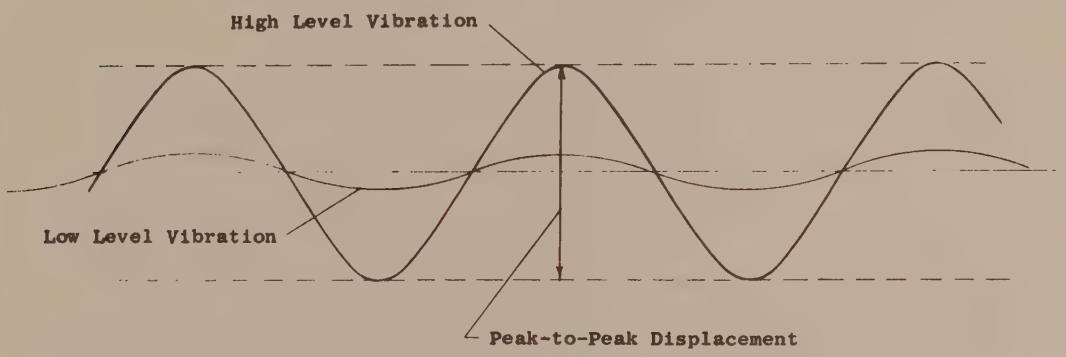
A scope jack and recorder jack are provided at the rear of the instrument; the first permits the visual study of the vibration waveform; the latter permits the graphic study of the vibration. The signal from the scope jack should be connected into a high impedance amplifier with an input impedance of at least one megohm; the scope jack provides an AC signal equivalent to approximately 17 volts RMS at full scale indication on the amplitude meter.

The signal from the recorder jack should be connected to a recorder through a preamplifier with an input impedance of at least 50,000 ohms; the recorder jack provides a DC signal equivalent to approximately 1 volt at full scale indication on the amplitude meter.

A 117 volt, 50/60 cycle, 2 wire accessory outlet is available at the rear of the console for operation of supplementary equipment.

OPERATION

The IRD Model 601 Vibration Analyzer is designed to measure the peak-to-peak displacement and maximum velocity of vibration and pinpoint the source. When unbalance is the cause, it serves to balance the rotating parts in-place, without costly dismantling of machinery. The instrument also serves as the electronic brain of dynamic balancing systems used in plant maintenance and production for dynamic balancing of components prior to assembly.



The basic principle of the electronic operation of this instrument is as follows:

The vibration pickup transforms the mechanical vibration being observed into a corresponding electrical signal whose voltage is directly proportional to the amplitude of the vibration. This signal is then amplified in the electronic circuit and registered on the amplitude meter and on the frequency meter. The variable filter, when used, eliminates all other frequencies of vibration except that to which it is tuned. The signal from the pickup also normally triggers the stroboscopic lamp in synchronization with the frequency of the vibration (an internal oscillator is also incorporated with which the flash rate of the lamp can be manually controlled if desired).

To prepare the Vibration Analyzer for operation, follow these steps:

Step 1 - Connect the power cable to a 117V, 50/60 cycle outlet and to the receptable at the rear of the instrument.

Step 2 - Screw the probe to the pickup and connect the pickup to the console by means of the cable provided.

Step 3 - Connect the stroboscopic lamp to the console by means of the cable provided. The connector at the console end of the cable is of the lock-on-type and is attached by pulling back the outside connector barrel and attaching the cable to the console.

Step 4 - Turn on the instrument by turning the amplitude range selector switch from the OFF position.

The instrument requires five to ten minutes warm-up period for optimum operation.

Step 5 - Set amplitude range selector to TEST position; set frequency range selector to 5 position with filter out. The amplitude meter should read approximately .5 to .6 full scale, and the frequency meter should read the powerline frequency in CPM (3600 CPM for 60 CPS power). These values have been preset to determine if the instrument is working properly. The filter can be switched BROAD and the tuning of the filter checked at 3000 CPM or 3600 CPM, depending on the line frequency.

To operate Model 601 Vibration Analyzer, follow these steps :

Step 1 - Place the vibration pickup at the locations where the vibration is to be measured or analyzed.

Step 2 - The LO HI Damping Switch is normally used in the LO damping position for vibration frequencies above approximately 10 CPS (600 RPM). At vibration frequencies below approximately 10 CPS increased damping (HI position) will reduce the meter needle fluctuation.

Step 3 - Set the amplitude range selector to the least sensitive range (100); if the meter indicates less than 30 mils, change ranges until you obtain an up-scale reading.

Step 4 - Set the frequency range selector to the desired range.

Step 5 - Set filter control to BROAD position or SHARP position as required.

The IRD Model 601 Vibration Analyzer serves three purposes, namely to measure vibration, to pinpoint the cause, and to correct unbalance in-place. When a component requires to be balanced in a balancing machine (IRD Model 102), the analyzer serves as the electronic brain of the machine.

MEASURE VIBRATION - Any machinery having rotating components has a certain amount of vibration. When it becomes excessive, this vibration will cause undue wear to the machinery. To remedy this situation, the vibration must be periodically measured to assure that it is within tolerances.

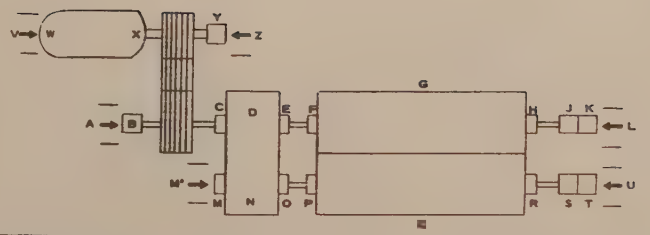
This is effected by measuring the overall vibration, and the vibration of each component in the machinery. The readings obtained can be recorded on charts such as figure 3. This chart includes the reading positions, the space to record displacement, frequency, and when available, the manufacturer's vibration tolerances. Each time readings are taken, they are recorded and compared with previous readings.

PINPOINT THE CAUSE - Once the instrument has determined that excessive vibration exists, the next step is to pinpoint the cause, or to troubleshoot the machinery. The following are the steps to be taken to pinpoint the cause of vibration. These are not necessarily in their order of importance because each individual problem requires its own order of steps.

1 - Determine the nature of the difficulty on the equipment involved; find out how long the trouble has been occurring, whether any changes were made in the equipment which may have precipitated the trouble, and whether or not any steps have been taken in an attempt to correct the trouble.

2 - Become familiar with the equipment by making a thorough examination of its component parts; determine the approximate speeds involved in the rotating components associated with the equipment. Place reference chalks marks on rotors, belts, etc.

3 - Measure the background vibration at the critical points on the equipment with the equipment completely shut down. This is the lowest level of vibration which can be attained on the equipment by taking corrective measures within the equipment itself; in the case of precision equipment such as precision machine tools the principle source of trouble is quite often transmitted vibrations from exterior sources and very little difference will be detected in the level of vibration with the machine running and the machine shut off completely. In any event, if the Vibration Analyzer detects the major source of the transmitted vibration, note this for future correction of the difficulty.



LOCATION	DATE BUILT
BLOWER SERIAL NO.	DATE INSTALLED
DATE TESTED	TESTED BY
HAND (L) (R)	
STD. FILTER	
V = VERTICAL PROBE _____ _____	F = FREQUENCY
H = HORIZONTAL PROBE _____ _____	V & H = VIBRATION AMPLITUDE IN INCHES

		EFF.	R.P.M.	AMP'S.		A	B	C	D	E	F	G	H	J	K	L	M	M'	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
TEST NO.	BLOWER NO.				V																										
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TEST NO.	BLOWER NO.				V																										
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REMARKS

Figure 3 - Vibration Chart.

4 - Place the equipment into operation and again measure the vibration at the critical points. Determine the predominant cause of the vibration by relating the frequency of the vibration (filter out) to the various components and characteristics of the system under study; use the stroboscopic lamp to determine whether the vibration is in synchronism with any rotating or oscillating components within the system. In cases where many components in the machine are completely sealed and cannot be observed with the stroboscopic lamp, it is helpful to have available a blueprint of the equipment in order that the frequency of the vibration can be related to the speed of some interior component. For rotating components which are visible, the stroboscopic lamp can be used in the OSC position to determine the rotating speed and slow down the rotating motion for visual observation of the component while they are running.

5 - When the vibration is measured at the critical points on a machine, a condition will sometimes be observed in which a "beat" or unsteady frequency reading is obtained due to the presence of more than one predominant source of vibration. The amplitude reading is also unusually somewhat unsteady. With these indications, use the variable filter to determine the various frequencies of vibration present, and the causes of these frequencies. When tuning the filter, the following procedures are recommended:

a) Turn the filter switch to the BROAD position and tune the filter carefully from lower to higher frequencies by scanning as you would with a radio tuner.

b) Select the highest possible range on the amplitude range selector (1/3 full scale or more) for maximum accuracy.

c) As the filter is being tuned, the presence of a measurable frequency component will be indicated by a steady frequency meter reading. When this is observed, tune to a peak amplitude indication.

d) Better rejection of vibrations at frequencies other than the one to which the instrument is being tuned, will be obtained by using the SHARP filter position.

6 - Correct the major cause of vibration and again measure the vibration at the critical points. Determine the remaining sources of trouble, if any, and correct these as required. The level of vibration to which the machine is corrected is dependent upon many factors, which may at times be (1) whatever level is necessary to obtain satisfactory operation from the machine, (2) a vibration level specified by commercial tolerances or established tolerances, (3) the background level beyond which the vibration level cannot be reduced without correcting sources of trouble outside the machine, (4) the lowest level which can be obtained without major redesign of the equipment, or (5) the level which has been proved to be satisfactory by previous experience.

NOTE: Do not try to compute the frequency of vibration by the number of images obtained when observing a reference mark on the rotating part. Use the frequency meter.

7 - In cases where there are many various components in a given assembly which can be operated separately, it is sometimes helpful to operate each component one

at a time in order to determine which component is the major contributor to the overall amplitude of the vibration; the analysis can then be simplified by operating this section of the machine separately and correcting the source of difficulty.

When using the stroboscopic lamp, it is important to remember that the flash rate of the lamp is not normally controlled by the operator, but by the vibration signal. However, when on OSC position, the lamp flashes are adjusted with the tuning knob until the part being studied appears stopped. The lamp then becomes a tachometer.

When using the unit as a stroboscopic tachometer, with the switch in the OSC position, adjust the flash rate of the stroboscopic lamp to its maximum rate (5000 flashes per minute) by means of the tuning knob. Slowly reduce the flash rate until the rotating part under observation appears to be stopped or frozen as a single image. Record this flash rate as R_1. Continue to reduce the flash rate until the part again appears stopped, being very careful not to miss any flash rate at which this occurs. Record this flash rate as R_2. The rotating speed may then be determined as follows:

$$RPM = \frac{R_1 R_2}{R_1 - R_2}$$

Example:

By following this procedure, it is determined that the rotating part is visually "frozen" at flash rates of 4000 flashes per minute and 3000 flashes per minute.

$$RPM = \frac{\text{4000 times 3000}}{\text{4000 minus 3000}} = \frac{12000000}{1000}$$

RPM = 12000 Revolutions per minute

In this example, the rotating part would also be "frozen" at flash rates of 2400, 2000, 1714, 1500, etc. flashes per minute (every submultiple of 12000 flashes per minute) and any adjacent pair of readings can be used to determine the speed. For instance, if the 2400 flashes/minute and the 2000 flashes/minute readings were used, the calculation would be:

$$RPM = \frac{\text{2400 times 2000}}{\text{2400 minus 2000}} = \frac{4800000}{400}$$

RPM = 12000 Revolutions per minute

Using the tuning control and the three lower positions of the frequency range selector, the flash rate can be varied from 150 to 5000 flashes per minute. The internal oscillator is not operative on the highest position of the frequency range selector.

There is a very useful feature incorporated in the Model 601 to facilitate tuning the the filter to the precise speed of the rotating component. Identical frequency determining circuitry is used for both the filter and the oscillator. If the oscillator is tuned so that the flashing rate of the strob lamp is in synchronization with the rotational speed of the part and the filter-OSC switch is switched to filter "in", the filter will be precisely tuned to the rotating speed.

Relative phase is measured when the strob lamp is being triggered by the signal vibration pickup by virtue of the fact that the strob light is not only triggered once for every cycle of vibration but also is triggered at one particular instant throughout the cycle. In other words, if a motor bearing is vibrating back and forth to the left and right in a lateral direction, and a keyway or reference mark on the motor shaft is being observed with the stroboscopic lamp, the angular position of the keyway or reference mark as observed when the pickup is applied to the left side of the bearing would be directly opposite or 180 degrees out of phase with respect to the angular position as observed when the pickup is applied to the right side of the bearing.

Typical vibration characteristics resulting from specific troubles are as follows:

1 - BEARINGS - A rough anti-friction bearing results in a relatively high frequency of vibration which is several times the frequency of the rotating member which is mounted in the bearing but not necessarily a direct multiple of that speed. The frequency reading is usually unsteady, and the amplitude reading may be somewhat unsteady also. The vibration due to a rough bearing of this type may be distinguished from high frequency electrical vibrations by virtue of the fact that the bearing vibrations will continue even after the electrical driving power is removed and the rotating member mounted in the bearing is coasting to a stop.

2 - BEARINGS - An anti-friction bearing can cause vibration due to the fact that the inner and outer races possess a certain amount of angular misalignment. This vibration will occur primarily in the end-wise or axial direction with respect to the shaft which is mounted in the bearing and occurs at a frequency equivalent to the rotor speed.

3 - NON-CONCENTRICITY - Lack of concentricity in an anti-friction bearing causes vibration which usually becomes apparent only at a low level of vibration when a precision degree of balance is being accomplished on the equipment which is running in the bearing. This may result in a vibrational frequency equivalent to the rotational speed of the part running in the bearing; the characteristics are such that it acts like an unbalance which shows up only in one radial direction (horizontal, vertical, or some other specific angle). The equipment can be balanced to a very low level with respect to the vibration in one direction but will not possess a low level of vibration in another.

4 - EXCESSIVE CLEARANCE - Conditions of excessive clearance within a sleeve bearing can be detected by the difference in the amplitude reading which is obtained on the bearing housing in comparison with the amplitude which is obtained by directly measuring the vibration on the shaft which is running in the bearing.

5 - BELTS - Belt vibrations can be set up in which the frequency of vibration is equivalent to the rotational (not peripheral) speed of the belt or a multiple of the rotational speed. In such a case the stroboscopic lamp will "freeze" or "stop" a chalk mark placed on the belt, and "freeze" or "stop" the mark

in one certain area or position or several positions in the event that the belt vibration is a multiple of the belt rotational speed. Belt vibrations are and are usually low in frequency due to the fact that the rotational speed of belt drives is usually low. In cases where a multiple belt drive is being used and several belts may be causing the overall vibration, the observation of one of the belts with the stroboscopic lamp may show a tendency to stop a mark on the belt in one given position (the mark would appear in one area of the belt more often than in other areas) rather than a fixed "stopping" of the belt.

6 - AERODYNAMICS - Aerodynamic vibrations may arise from several sources, such as (1) unequal pitch on the blades of a propeller-like system in which the axial force against one blade is not equal to the axial force against the remaining blades, resulting in a vibration which occurs at a frequency equivalent to the rotating speed and is primarily (but not totally) acting in the endwise or axial direction, (2) blade flutter may be encountered at the resonant frequency of the blades if there is some source of energy at that frequency to excite the blade or blades, and (3) duct work, shrouds, piping, etc., can be excited to resonance by the flow of air, gas, or liquid through the system.

7 - HYDRAULICS - Hydraulic vibrations may result from such causes as cavitation in pumps, vibrations excited by fluid flow, etc. Hydraulic systems are sometimes a source of troublesome vibrations on precision machine tools; this may be due to unbalance in the pumps, and is normally corrected by isolating the pump from the remainder of the machine.

8 - MECHANICAL - In practical vibration problems, a condition frequently arises in which the frequency of vibration is twice that of the rotating speed on a particular component which is being analyzed; this is usually referred to as a "double frequency" or a "double picture" (When the stroboscopic lamp is used to observe the rotating component, the vibration picked up by the pickup triggers the stroboscopic lamp twice for each revolution of the rotating part, and a reference mark appears to be stopped in two positions rather than one). This is usually an indication of some mechanical source of vibration such as looseness, rubbing, wear, excessive play between mating parts, etc. One exception to this is the case of reciprocating components being driven from a drankshaft; in this case a "double frequency" arises naturally from the forces within the system.

9 - ELECTRICAL - Some types of vibration may be electrical in nature, such as case vibrations in transformers which are induced by the alternating electromagnetic fields. Another source of electrical vibration which is frequently encountered is torque pulses in single phase electrical motors; these result from the fact that the movement of the rotor throughout one revolution is not constant but consists of a series of jerks as the rotor passes each pole within the motor. This vibration occurs at synchronous frequency or some multiple of synchronous frequency.

10 - GEARS - Gears may be the cause of vibrations, the frequency of which is dependent upon the nature of the trouble and the character of the assembly in which the gear is mounted. For example, if tooth interference is taking place between two mating gears, the frequency of vibration on one gear will be equivalent to the product of the number of teeth on the gear and the gear

speed in revolutions per minute. If a gear has a high tooth, the frequency of vibration will be equivalent to the product of the gear speed in revolutions per minute and the number of other gears with which the gear meshes.

11 - OIL WHIRL - In equipment which is designed to operate at a speed well above the shaft is running in lubricated sleeve bearings, a condition may arise in which "oil whip" may develop within the bearing and cause the shaft to "whirl" at a speed which is lower than the rotational speed. This "whirl" speed is often in the order of one-half the rotational speed, and the resultant vibration is approximately equivalent in frequency to one-half the rotation speed. This condition is usually corrected by altering the design of the bearing or changing the conditions of lubrication.

12 - RESONANCE - In some cases the reason that trouble is being encountered can be traced to the fact that system resonance is occuring at or near the operating speed of some component within the system, and vibrations which otherwise would be small are magnified. This can be detected by shutting off the power source and noting the manner in which the amplitude of vibration varies as the equipment coasts to a stop. By observing the amplitude and frequency readings while the equipment is slowing down, the frequencies can be noted at which the amplitude readings rise to a peak; these are the resonant or critical speeds. If the amplitude falls off very sharply as the equipment slows from operating speed, it is then apparent that the equipment is running near resonance. When this is the case, the amplitude of vibration can be reduced to a low level by (1) balancing to a high degree of precision the component which is exciting the resonance, or (2) modifying the system to change the resonance. Unless it is practical to obtain a precision balance and maintain it throughout the life of the equipment, some effort to change the resonance is usually warranted.

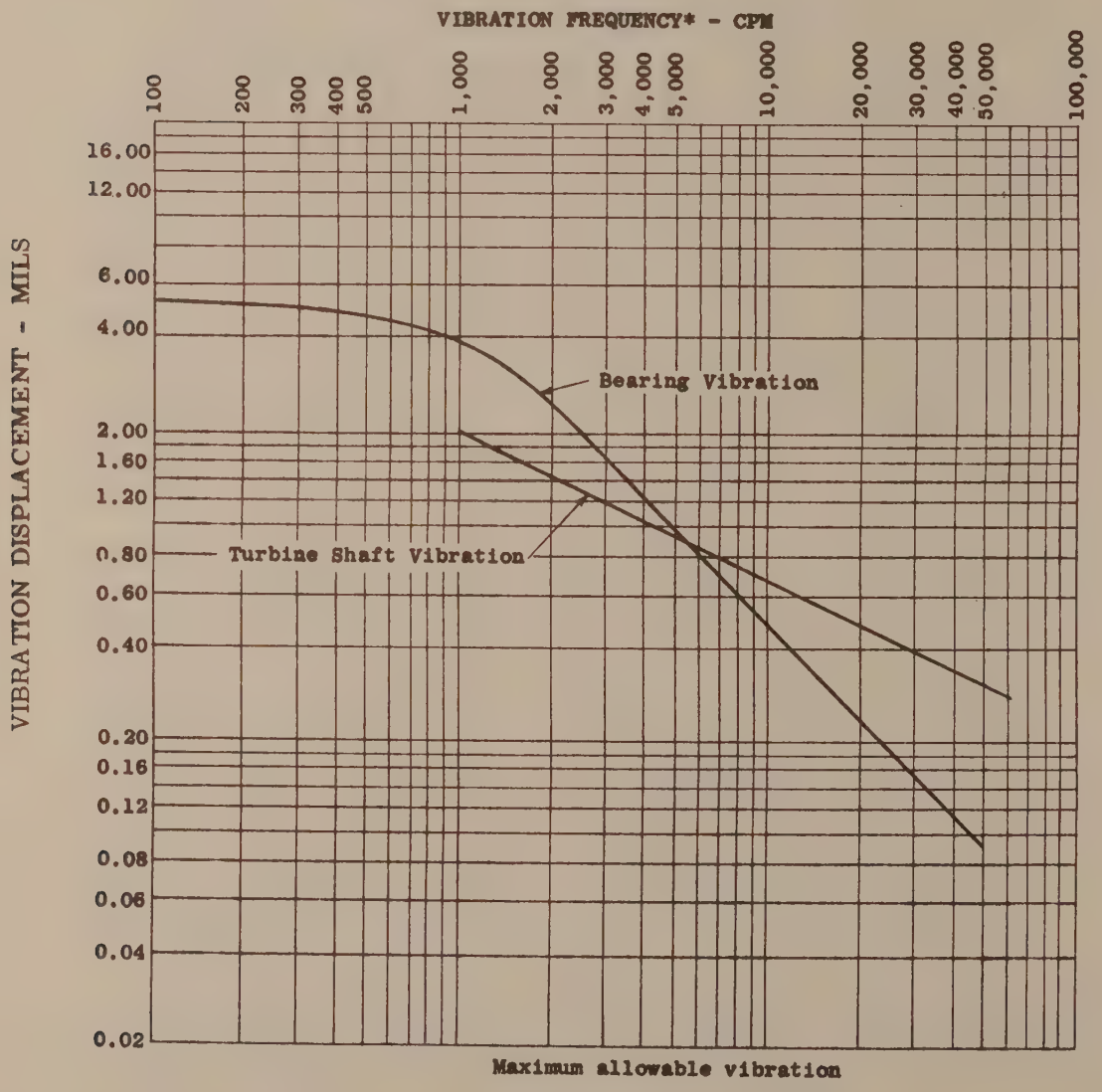
13 - MISALIGNMENT - Mechanical troubles such as misalignment or bent shafting can cause vibration difficulties Since these conditions result in the rotating mass being displaced from its correct operating axis, the system may actually be out of balance although weight distribution within the part if not the primary source of trouble; the indications which result may be similar to those due to ordinary imbalance, but normal balancing procedures may not completely solve the trouble if the mechanical troubles are of a sufficiently major degree. Misalignment or bent shafts may result in a vibration frequency equivalent to twice the rotating frequency, resulting in a characteristic "double frequency" of vibration; the exact manner in which a misalignment will manifest itself depends upon the degree of misalignment, type of bearings, type of couplings, and equipment being used. It is recommended that the alignment always be checked if it is suspected as a source of trouble. This type of mechanical trouble often causes a high level of vibration in the endwise or axial direction on a bearing.

In cases where the shaft vibration should be measured, the pickup can be placed at the bearing points. However, if this is impractical, measurements can be taken by using a sharp-edged wooden probe such as the IRD PH-1 shaft stick. The probing end of this wooden extension should be razoredged and V-shaped to ride against the shaft. Hard wood such as maple should be used. Lubricating oil should be applied to permit riding ease on the shaft.

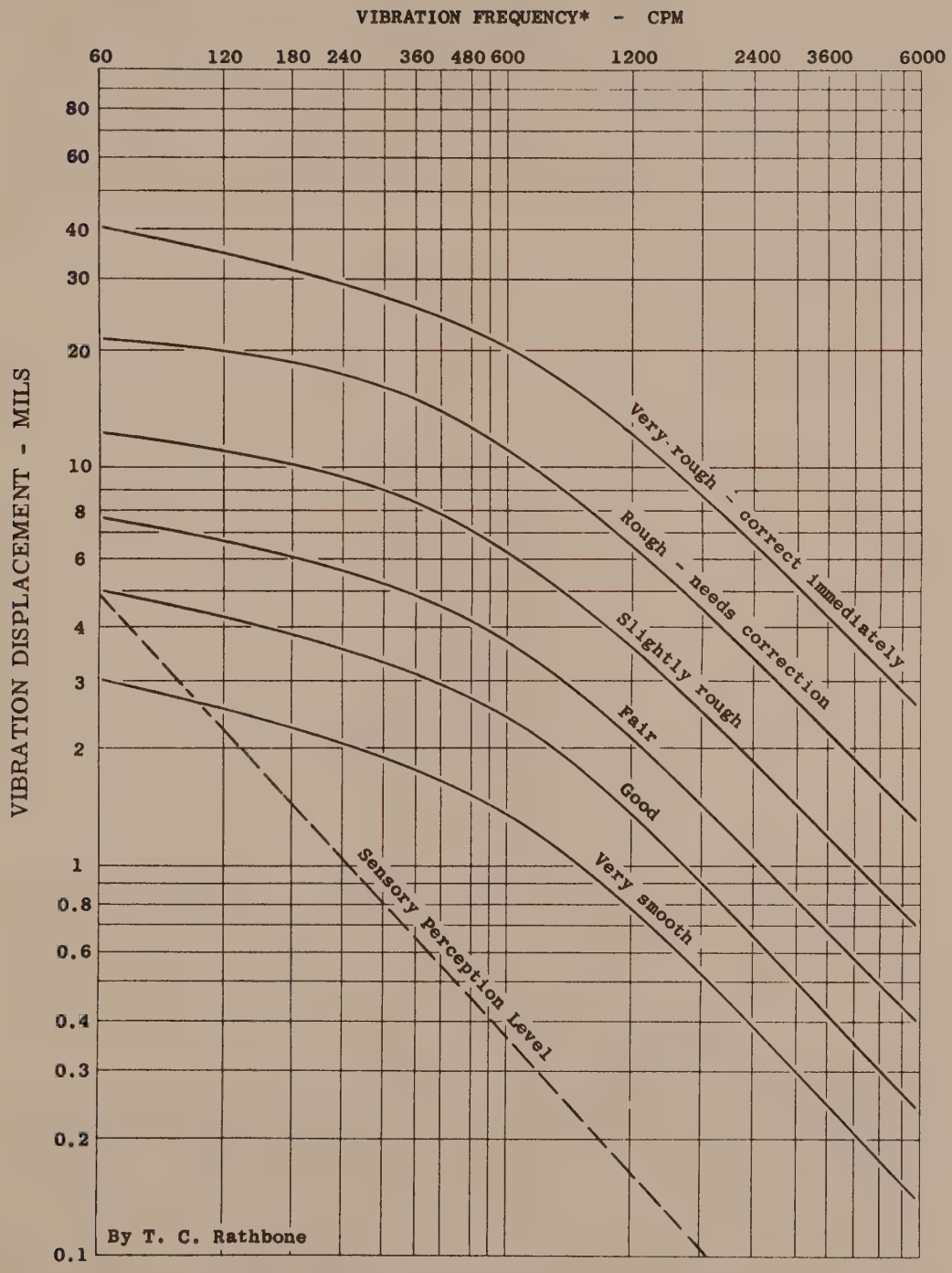
The charts on the next pages illustrate the approximate degree of vibration which can be tolerated on machinery. The values of the second chart (by T. C. Rathbone)

are based on practical data obtained from a large number of machines and are only an approximate guide. Wide variations from these values may be expected from individual machines. This chart was established for heavy rotating equipment; the vibration levels are much too excessive to be applied to precision machine tools and precision equipment. This chart should definitely not be used for such machinery.

The values on the first chart are for shipboard equipment as noted in MIL-STD-167 (SHIPS) 12/20/54.



* Frequency corresponds to RPM when dynamic unbalance is the cause of vibration



* Frequency corresponds to RPM when dynamic unbalance is the cause of vibration

BALANCING PROCEDURES

model 601

IN-PLACE BALANCING

BASIC REQUIREMENTS

A. Vibration must be due to unbalance.

1. Stroboscopic lamp "freezes" or "stops" rotating part which being triggered by the vibration pickup. If necessary, the filter can be used to screen out background vibrations.

B. Means of adding or removing correction weight must be available on rotating part.

C. Means of maintaining constant speed during balancing runs is advisable.

1. Precise speed control is not required unless the system is being balanced at a mechanically resonant speed.

a. In using the filter, if the speed control is not within 1% from run to run, the filter should be reset for each run by switching to OSC and adjusting the tuner until the strobe light is in synchronism with the rotation.

b. When balancing at mechanical resonance, care should be taken that the phase shift variation with speed does not cause false readings.

GENERAL PROCEDURE

A. Place reference mark on rotating system for phase determination.

1. Keyway, scratch, etc. can be used for reference mark if first set of data is taken before equipment is shut down.

2. Place mark radially from rotating axis.

3. The end of a shaft is often the best place for the reference mark, since the position is very readily observed.

4. If there is a possibility of looseness or slippage between mating portions of a rotating assembly, mark each portion in order that it may be observed whether or not the physical relationship of the various parts of the assembly is constant throughout the job.

5. Mark can be placed at either end of a rotating assembly, but all data must be taken from one end throughout the balancing procedure.

6. If only a side view is available, use a sequence of numerals around the rotating part.

a. Numbered tape is sometimes helpful.

B. Locate points where vibration measurement will be taken

1. Use points where sensitivity is high (high amplitude of vibration) and frequency reading steady at speed or rotating part.

   a. Compromise to measure in the same direction when taking data at both ends.

2. Take measurements as close to bearings as possible.

   a. If it is known that the shaft is true and has a smooth surface, it is sometimes advantageous to measure vibrations directly on the shaft.

3. On some equipment, balancing can be accomplished by measuring on a housing, foundation, support, pipe or other extension, etc.

4. Take measurements from same point or points and in same directions throughout balancing runs.

   a. One point usually sufficient for each balancing plane.

   b. Both vertical and horizontal measurements for each balancing planes sometimes helpful if conveniently taken.

C. Observe and record background level of vibration with apparatus shut down and not running.

1. Background level is lowest level to which equipment can be balanced.

2. If the Vibration Analyzer diagnoses the source of background vibration, correct or note for future correction.

D. Observe and record original running conditions.

1. Record amplitude in inches or mils.

2. Record relative phase angle in degrees or apparent clock position in hours.

3. Repeat original runs if (1) instability is suspected, (2) equipment appears to be running near mechanical resonance, or (3) poor speed control is suspected.

   a. Check for consistency in readings.

   b. Use oscillator to ensure that runs are being taken at exactly the same speed if poor speed control is being encountered.

What is unbalance -

One of the most common causes of vibration in machinery is unbalance of the rotating components. This unbalance is mostly due to a heavy spot or weight for which there is no compensation on the opposite side of the rotating part. This heavy spot or weight may be caused by faulty design or faulty mechanical assembly.

The common term used to specify the degree of unbalance is ounce-inches; similar terms such as pound-inches, gram-inches, and micro-ounce-inches are sometimes used. These terms indicate the amount of weight and the distance from the center where the weight should be applied. For example, if a two-ounce weight is added to a flywheel at 5 inches from the center, the unbalance is expressed as 10 ounce-inches; if the weight is one ounce at 10 inches or 10 ounces at one inch, the result is also 10 ounce-inches. The same terms apply if a part is not mounted on its true center. For example, if a 20 pound (320 ounces) pulley is mounted two thousandths of one inch. (.002") off center, the resulting unbalance is 320 x .002 = 0.64 ounce inches.

Balancing problems in production and in the field are normally classified as single-plane, two-plane, and multi-plane problems.

SINGLE PLANE

TWO PLANE

Single-plane problems are those in which the diameter of a rotating part is large as compared to its length, such as most grinding wheels, single groove pulleys, three and four bladed fans, pump impellers, flywheels, etc. Single-plane unbalance is often called static unbalance because, if it is severe enough, it can be detected by resting the part on rails and letting the heavy spot fall to the bottom; for example, when a bicycle wheel is rotated freely, the air valve (the heavy spot in this case) will fall to the bottom.

A part which is relatively long as compared to its diameter, such as an armature, a spindle, a shaft, etc., cannot be balanced in a single plane. This type of unbalance is called dynamic unbalance and is referred to as a two-plane problem. If the part is extremely long, or if the rotating speed of the part causes the weight of the heavy spot to "bend" the part, it may be necessary to balance in several planes.

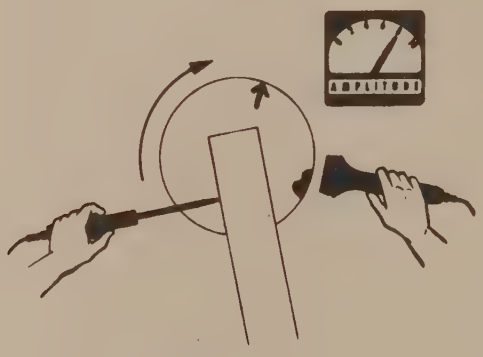
Balancing Methods -

There are two basic methods of determining the location and the weight to be added or taken-off; they are the five-step method and the vector method. In production balancing, a simpler and quicker method will apply.

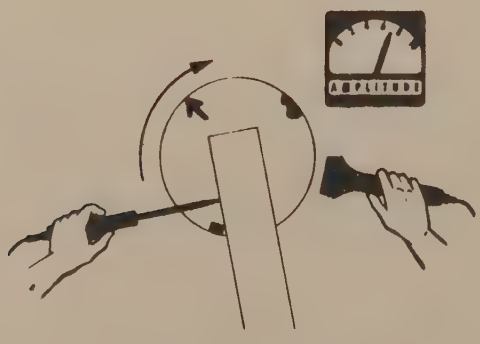
The five-step method is simple and convenient when the number of trial runs is not important and when the part is easily started and stopped. To illustrate this method, consider the case of a pulley as being the cause of predominant vibration.

Step 1 - Make a reference mark (chalk mark, keyway, paint spot, etc.) on the pulley in order to see where the mark is each time the stroboscopic-lamp is triggered.

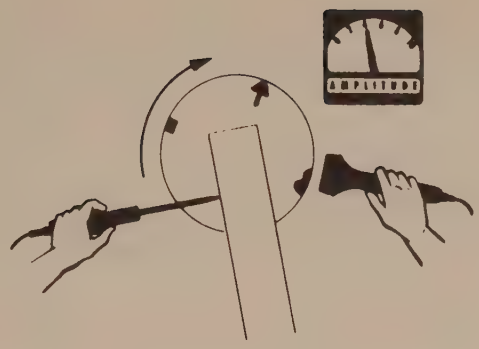
Step 2 - Place the pickup on the bearing or housing nearest the pulley and observe amplitude meter and position of mark.



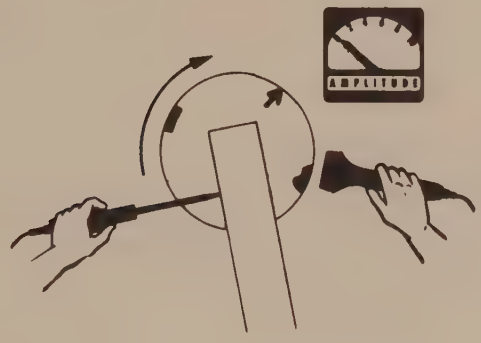
Step 3 - Add a weight to the pulley and observe the angular shift of the reference mark.



Step 4 - If the mark has moved, shift the weight in the opposite direction of the move until the mark returns to its original position or directly opposite.



Step 5 - Add or subtract weight until an acceptable degree of balance is obtained.



Rules of five-step method -

1. Always compare conditions with the first run.
2. Always move the weight in opposite direction of the shift of the mark from initial run.
3. Move the weight less than 90 degrees if vibration decreases.
4. Move the weight 180 degrees if the mark remains in the same original position and vibration increases.
5. When the mark returns to the original position, increase the weight until balance is obtained.
6. When the mark moves directly opposite its original position, reduce weight until balance is obtained.
7. Always hold the pickup at the same location and in the same direction with each run.

In cases in which it is necessary to balance a part often such as a grinding wheel, the following short cut method can be used. First the wheel is balanced using either the five-step or the vector method, noting the location of the heavy spot; then, pro-

viding the mass of the wheel is approximately the same, and the pickup is held in the same direction as in the first balancing, the heavy spot will be at the same location in relation to the reference mark each time the wheel is to be balanced.

For example:

FIRST TIME SECOND TIME THIRD TIME

Note that the first time the wheel was balanced, the heavy spot (sometimes called the flash angle) was at 6:00 and the reference mark was at 1:00; subsequent balancings produced a different location of the reference mark but the heavy spot remained at 6:00. Consequently, to reduce the five-step method to one step, one is required to notice the original location of the heavy spot. Thereafter, this spot will always be in the same location in relation to the reference mark.

The vector method is most efficient when time and number of runs are important.

To illustrate the method, consider the case of a thin flywheel:

1. Make a reference mark as in the five-step method.

2. Place the pickup on the bearing or housing nearest the flywheel and record amplitude meter readings and position of the mark.

   Example: .060" with mark at 1:30.

3. Draw line "O" (original) on paper at the same angle as that of the mark, and with a length proportional to the amplitude.

4. Add a test weight the size you think is approximately correct at any place on the flywheel.

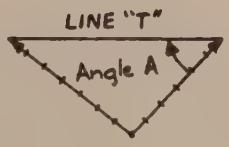
5. On this run, record the new amplitude readings and the new position of the mark.

   Example: First run - .060" at 1:30.

   Second run - .070" at 10:30.

6. Add line "R" (result of adding weight to original) to the diagram with length and angle corresponding to the new reading.

7. Draw a line from the end of Line "O" to the end of line "R". This is now line "T".



The angle "A" between line "O" and line "T" tells the direction and degree that the weight should be shifted. In the above example, the weight should be moved 55 degrees clockwise from its present position. The weight is always shifted in the direction opposite the shift of the mark.

The length of the line "T" represents the effect of the test weight. The length of line "O" represents the effect of the original imbalance. The test weight should be increased or decreased according to the ratio of line "O" to line "T". In the above example, if the test weight is 10 grams, line "O" is two inches long, and line "T" is three inches long, the correct weight to be used is 10 x 2/3 - 6-2/3 grams.

8. This will not always work out on the first run because the diagrams cannot be 100% exact, and the length of the lines cannot absolutely correspond to the exact amount of imbalance. Further runs can be made and another run taken.

   The new vibration condition is:

   First run - .060" at 1:30.

Second run - .070" at 10:30.

Third run - .010" at 6:00.

Angle "A" indicates that the weight should be shifted slightly counterclockwise (about 10) and the length ratio of line "O" to line "T" shows that the weight should be reduced slightly.

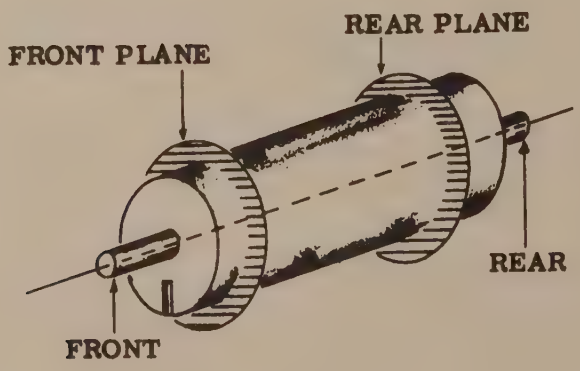
9. For finer balance, repeat this procedure, always comparing readings with the original conditions.

Two-plane balancing problems may be solved by using the same procedures as described in the previous paragraphs, and treating each end as a separate problem. However, the vector method should be used because it is the more accurate of the two in this case. When using this method, the reference mark and its shifts should always be observed at the same end of the part regardless which end is being balanced. Each step of the vector method should be followed. However, the amplitude readings must be taken at both ends of the part regardless which end is being balanced.

In some two-plane problems, after balancing one plane then the other, it may be necessary to rebalance the first plane again. This is due to cross-effect that may be introduced in the rotating part when a weight is added to one plane; this cross-effect may cause vibration at the other plane. Cross-effect is generally more severe when the correction planes are relatively close together.

In a typical two-plane problem, assume that the reference mark is the keyway and that the initial readings are:

	FRONT	REAR
Run #1	.018" at 6:00	.019" at 5:00



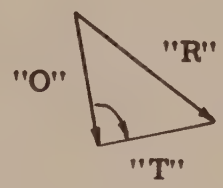
Where, as in the case above, the amplitude readings and the angle of the mark are comparable at both ends, the imbalance is roughly at the same angle and the amount similar at each end. In such a case, a single-plane correction at the center, or equal weights at each plane, (sometimes called a "static" correction) will probably remove most of the imbalance. To make such a correction, one must assume that the rotating member is fairly symmetrical and that the rigidity of the bearing mounts at each end is comparable. Assuming then that we add 10 ounce-inches in line with keyway at each plane and that the readings are:

	FRONT	REAR
Run #1	.018" at 6:00	.019" at 5:00
Run #2	.021" at 5:00	.023" at 4:00

Draw a vector sketch for each plane to determine the proper moves.

FRONT

REAR



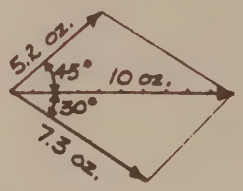
These sketches indicate that we should move the weights 100 degrees clockwise from the keyway and increase then to 15 ounce-inches at each plane. The readings now becomes:

	FRONT	REAR
Run #1	.018" at 6:00	.019" at 5:00
Run #2	.021" at 5:00	.023" at 4:00
Run #3	.005" at 6:00	.003" at 2:00

Since the reference mark now appears at different angles for each end, further attempts to statically balance the part would be useless. The next step is to consider each end as a separate balancing problem starting with the front because the amplitude is greater at that end. The corrections already made should not be disturbed; this now is a new problem. Start with run #3 as the original run.

In many two-plane balancing problems, the phase lag at each end of the system will be the same or very nearly the same. Therefore, after the angle at which the heavy spot fires the light has been determined at one end, this information may be used to locate the point on the other end at which the trial weight should be added.

There are occasions when the weight must be divided between two positions because there may be only certain places on the part on which correction can be made. In these cases, a vector sketch can be drawn to determine the amount and position of each weight. For example, suppose 10 ounce should be added at a certain point, but the only places available are at 30 degrees clockwise and 45 degrees counter-clockwise from the spot where the weight should be added. The sketch is drawn to scale as a parallelogram with the 10 ounce line as the diagonal; the length of the sides indicates the amount of weight to be added at each piece.



As seen in the above diagram, 7.3 ounces should be added at 30 degrees clockwise and 5.2 ounces should be added at 45 degrees counter-clockwise. Note here that the two weights amount to more than 10 ounces; that is normal because, when correction weights are divided, a greater weight is required than if it were placed in one location.

In balancing various types of components, temporary weights are normally used before permanent weights are attached. The only exception is in production balancing where the system has been previously calibrated by the flash-angle method to quickly determine the location and amount of balancing correction.

Typical means of applying temporary weights are:

1. Using balancing clay on the rotating part.

2. Adding bolts, nuts, or washers to through holes, tapped holes, or threaded studs.

3. Clipping weights and U/clamps (mounted in such a manner that centrifugal force helps in holding the weights.

4. Adding layers of short lengths of tape (for fine correction on very light components).

5. Adding weights in accordance with balancing provisions by the manufacturer of the equipment being balanced.

6. Fastening weights to metal baling bands strapped around the part (for cylindrical surfaces on which there is no ready means of adding weight).

After balancing has been obtained with temporary weights, these must be replaced by permanent type ones. It is very important to remember that the permanent cor-

rection must be equal in ounce-inches to the temporary weight. This is also very important when the final correction cannot be made at the same radius as the temporary weight was located. Typical means of making permanent corrections are:

1. Welding metal weights (the weight of the welding material must be taken into consideration).

2. Soldering.

3. Permanently attaching weights in accordance with provisions made by the manufacturer.

4. Adding bolts, nuts, or washers to through holes, tapped holes, or threaded studs.

5. Drilling, grinding, or filing.

6. Fastening clips or U-clamps permanently.

When balance correction is being made by drilling, grinding, or filing, it must be remembered that weight must be removed directly opposite from where the trial weight was added. In such cases where weight is removed, a shift of the reference mark may occur. In this case, the remainder of the weight should be removed in the opposite direction of the shift of the mark.

Model 600 or Model 601 can easily serve as the electronic brain to any IRD Dynamic Balancing Machines, thus eliminating costly duplication of instruments. No special tooling is required; simply connect the Analyzer to the machine.

MAINTENANCE and CALIBRATION

model 601

MAINTENANCE AND CALIBRATION

1 - GENERAL

The components used in the MODEL 601 VIBRATION ANALYZER have been selected and tested to provide long, trouble-free operating life. It must be recognized, however, that trouble may occur at some time during the life of the instrument. This section is included to provide useful information for the location and correction of such trouble.

INTERNATIONAL RESEARCH AND DEVELOPMENT CORPORATION will supply replacement components at current net prices. However, since most of the components are standard electronic and radio parts, we suggest you get them from your local dealer if possible. Be sure to consult your OPERATION MANUAL first to see what tolerances are required.

2 - MECHANICAL

The MODEL 601 VIBRATION ANALYZER requires no specific mechanical maintenance, beyond periodic inspection of mechanical elements during the course of normal operation. Should some mechanical element need replacing, a complete identification of that part should be forwarded to INTERNATIONAL RESEARCH AND DEVELOPMENT CORPORATION and a replacement will be returned imediately.

3 - ELECTRONIC

3-1 Tubes - The tubes used in this Vibration Analyzer are of the ruggedized industrial type, and as a result, can be expected to give long, trouble-free service. If a tube becomes inoperative for any reason, a replacement is recommended with either a ruggedized or a commercial tube. When tube replacement is required, the critical tubes which may affect instrument performance and calibration are:

Circuit Symbol	Type
V1	ECC83
V2, V4	5814A
V3	607

Whenever one of these tubes is replaced, the instrument should be checked and recalibrated, if needed, as outlined in the CALIBRATION procedure (Sec. 6-3 Preliminary Gain Adjustment).

3-2 Stroboscopic Bulb - In the event the STROBOSCOPIC BULB emits a continuous dull-blue glow rather than a blue-white flash, the bulb is continuously discharging. The bulb should be replaced as soon as possible. In case of any other malfunctions of the stroboscopic lamp, return the unit to the factory to be repaired.

3-3 Vibration Pickup - the VIBRATION PICKUP should always be returned to the factory to be repaired. Also, when returning the MODEL 601 to the factory to be repaired, always include PICKUP, Cables, and STROBOSCOPIC UNIT so that complete calibration can be effected.

4 - PERFORMANCE CHECKS

The following performance checks are recommended before proceeding with any major electrical maintenance. They are listed to direct the troubleshooting efforts toward the most probably source of difficulty.

The first consideration, of course, is to make sure the power is being supplied to the instrument. If not, check the fuse located on the rear panel of the unit A spare fuse is also located on this panel. Secondly, connect the STROBOSCOPIC UNIT and STROBOSCOPIC CABLE, remove the PICKUP CABLE and make the following tests:

4-1 Place the control in the OSC position with the FREQUENCY RANGE SELECTOR on the .5, 1.5 or 5 range; check whether or not the frequency reading can be varied using the TUNING CONTROL. If a proper frequency reading is not obtained, there is difficulty in the console.

4-2 If a steady frequency reading is obtained with the control in the OSC position, depress the push-button switch on the strob light to see whether the STROBOSCOPIC BULB is flashing. If the bulb does not light, check the bulb by replacement. CAUTION - the power should be turned OFF while the bulb is being replaced. If this does not provide satisfactory operation, check the continuity of the conductors in the STROBOSCOPIC CABLE by resistance measurement.

4-3 To check the operation of the AMPLITUDE METER, place the FREQUENCY RANGE SELECTOR on the 5 position, the FILTER in the OUT position, and the AMPLITUDE RANGE SELECTOR in the TEST position. An amplitude reading of approximately half scale (.5) and a frequency reading of 3600 should result. Place the FILTER in the IN position. Rotate TUNING CONTROL for a peak reading on AMPLITUDE METER. Meter should be reading approximately half scale (.5) and a frequency reading of 3600. If these two amplitude readings are not obtained then incorrect functioning within the instrument is indicated.

4-4 If the previous checks show satisfactory AMPLITUDE METER operation, the PICKUP should be connected. Proper pickup operation can be checked out by the fact that the slight motion of the hand holding the pickup with filter "OUT" should cause an erratic but appreciable reading of amplitude and frequency. The AMPLITUDE RANGE SELECTOR should be placed on the 0.1 mil range for this check. If this does not occur, failure had developed, and the PICKUP CABLE should be checked.

NOTE: Periodic checks should be made to determine whether any dust or debris has accumulated in the instrument. Particular attention should be given to the connectors which receive the vertical plug-in circuit boards.

5 - MAINTENANCE SERVICE

5-1 The SCHEMATIC (Drwg. # 601-1) is arranged to correspond as much as possible to the physical elements of the analyzer section of the instrument. The printed boards, for example, correspond to the schematic areas outlined and identified by number. Comparison of the tube requirements with the TUBE LAYOUT (Drwg. # 601-4) complete the association of the electronic circuitry with the physical layout.

VOLTAGE AND RESISTANCE MEASUREMENTS (Sec. 5-3) presented as a service aid were taken with an RCA Senior Voltohmyst. All measurements were made to chassis ground. Readings should be made on the most sensitive scale possible to minimize error.

5-2 Control settings required when making these measurements are as follows:

Control	Position
"AMPLITUDE-MILS"	100
"FILTER-OSC. SELECTOR"	OUT
"DAMPING"	LO
"FILTER-OSC. TUNING"	ANY
"FREQUENCY RANGE CPS"	ANY

PICKUP must be disconnected from analyzer.

CAUTION: When checking voltages on tubes V11, V12, and V13 use a test adaptor under the tube. Do not remove tubes from their sockets with power on.

VOLTAGE AND RESISTANCE MEASUREMENTS

VOLTAGE AND RESISTANCE - 601

5-3

Pin No.	V1 Resistance	V1 Volts Zero Sig.	V2 Resistance	V2 Volts Zero Sig.	V3 Resistance	V3 Volts Zero Sig.	V4 Resistance	V4 Volts Zero Sig.	V5 Resistance	V5 Volts Zero Sig.
1	260K	90VDC	Inf.	60VDC	260K	70VDC	26K	70VDC	330K	82VDC
2	1.1 Meg.	-.1VDC	1.1 Meg.	0	1.1 Meg.	4VDC	2.7 Meg.	0	3.3 Meg.	34VDC
3	1.5K	.7VDC	1.9K	2.5VDC	7.5K	5.7VDC	1.5K	3.5VDC	82K	36.5VDC
4	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC
5	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC
6	300K	84VAC	130K	111VDC	35K	240VDC	33K	240VDC	130K	240VDC
7	1.1 Meg.	-.15VDC	600K	55VDC	1.1 Meg.	60VDC	270K	68VDC	650K	15VDC
8	1.5K	.7VDC	0	59VDC	70K	70VDC	22K	76VDC	82K	36VDC
9	26K	18VDC 2.65VAC	26K	18VDC 2.65VAC	26K	18VDC 2.65VAC	26K	18VDC 2.65VAC	26K	18VDC 2.65VAC
	651-26 BOARD								600-15 BOARD	

Pin No.	V6 Resistance	V6 Volts Zero Sig.	V7 Resistance	V7 Volts Zero Sig.	V8 Resistance	V8 Volts Zero Sig.	V9 Resistance	V9 Volts Zero Sig.	V10 Resistance	V10 Volts Zero Sig.
1	100K	240VDC	33K	240VDC	540K	120VDC	360K	3.1VAC	1.1 Meg.	0
2	26K	62VDC	1.1 Meg.	31VDC	0	0	360K	3.1VAC	6.8K	4.8VDC
3	33K	72VDC	130K	69VDC	2.8K	4VDC		18VDC 3.5VAC	26K	18VDC 3.5VAC
4	26K	18VDC 3.5	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 2.65VAC	26K	18VDC 3.5VAC
5	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	26K	18VDC 3.5VAC	68K	8.6VDC	6.8K	4.8VDC
6	68K	170VDC	60K	240VDC	33K	240VDC	0	0	100K	240VDC
7	2.0 Meg.	72VDC	500K	0	550K	122VDC	0	0	6.8K	4.8VDC
8	33K	72VDC	4.8K	13VDC	35K	122VDC	X	X	X	X
9	26K	18VDC 2.65VAC	26K	18VDC 2.65VAC	26K	18VDC 2.65VAC	X	X	X	X
	600-15 BOARD Con't.						600-14 BOARD			

VOLTAGE AND RESISTANCE MEASUREMENTS

5-3 (Cont'd.)

VOLTAGE AND RESISTANCE - 601

Pin No.	V11 Resistance	V11 Volts Zero Sig.	V12 Resistance	V12 Volts Zero Sig.	V13 Resistance	V13 Volts Zero Sig.
1	2 Meg.	210VDC	100K	87VDC	Inf.	0
2	74K	150VDC	0	0	33K	240VDC
3	Inf.	150VDC	Inf.	7VDC	2 Meg.	600VDC
4	26K	18VDC 3.5VAC	0	0	2 Meg.	500VDC
5	26K	18VDC 3.5VAC	100K	87VDC	3 Meg.	210VDC
6	Inf.	150VDC	0	0	Inf.	0
7	64K	87VDC	0	0	1 Meg.	240VDC
8	100K	87VDC	X	X	1 Meg.	240VDC
9	26K	18VDC 2.65VAC	X	X	X	X
	600-14 BOARD Cont'd.				Baseboard	

6 - CALIBRATION

6-1 Normally, no adjustments are required for operation except when tubes are replaced. Before attempting these adjustments, a complete understanding of the procedure is necessary. A fifteen minute warmup should precede any adjustment.

6-2 For complete recalibration the following or equivalent test equipment should be used:

1) An accurate AC vacuum tube voltmeter such as the Hewlett-Packard Model 400B or equivalent.

2) An accurate signal generator capable of generating frequencies of excellent sinusoidal waveform over the frequency range of 5 CPS to 2000 CPS. (Hewlett-Packard Model 200 CD or equivalent)

3) Additional accessories

   a) AN3106B-10SL-4S connector

   b) 5/16" spin-tight

   c) 1/2" spin-tight

   d) Screwdriver - insulated

6-3 Preliminary Gain Adjustment - (See the SCHEMATIC Drwg. #601-1 and TUBE LAYOUT Drwg. 601-4)

The amplitude circuits are checked and adjusted, if necessary, by the following procedure: (See the TUBE LAYOUT Drwg. #601-4 for the location of controls.)

1) With the instrument off, zero the "AMPLITUDE" meter by means of the small adjusting screw located at the front center of the meter.

2) Turn the instrument on and allow it to warm up.

3) Apply a signal to the INPUT. Set the "AMPLITUDE-MILS" switch to the 1 mil position. Set the "DAMPING" switch to LO.

4) Adjust the signal generator for a signal input of 240 MV± 2% at 100 cycles per second. Adjust the AMP. Gain control for full scale deflection on the "AMPLITUDE" meter.

5) When replacing tubes listed in Sec. 3-1, the AMP. Gain control should be checked and adjusted if necessary.

NOTE: The signal generator voltage and frequency given above is a typical value corresponding to an IRD MODEL 544, 545, 546 PICKUP. For instrument calibration procedure using a pickup having a different value, see Section 6-6.

6-4 Calibration of the Frequency Meter - The "FREQUENCY METER" is provided with an adjustment for each frequency range. For maximum accuracy, each range must be individually calibrated. Approximately 3/4 scale reading has been arbitrarily chosen as the calibration point for each range. To calibrate the FREQUENCY METER proceed as follows:

1) Set the "AMPLITUDE-MILS" range switch to the TEST position and the "FREQUENCY RANGE" switch to 5K. The FREQUENCY METER should now read the line frequency in cycles per minute. If not, adjust the FREQ. METER ADJ. 5K (for 60 CPS line Freq.) control to obtain the correct reading. The .5K, 1.5K, 5K, and 15 K frequency ranges should now be set using an accurate signal generator. (See the TUBE LAYOUT - MODEL 601, for location and identification of the Freq. Meter Adj. controls).

NOTE: The above step calibrates the 5K CPM Frequency Range. The 5K CPM frequency range may also be checked using the signal generator; however, the accuracy of indication will depend on how closely the signal generator dial agrees with the line frequency.

2) Using an accurate signal generator, set the input signal frequency to 7 CPS. Adjust the signal amplitude to obtain an on-scale amplitude reading. Set "FREQUENCY RANGE" switch to .5 position.

3) The "FREQUENCY METER" should now read 420 CPM. If not, adjust the FREQ. METER ADJ. .5 control until a 420 CPM reading is obtained.

4) Set the input signal frequency to 20 CPS. Set the "FREQUENCY RANGE" switch to 1.5. Adjust the FREQ. METER ADJ. 1.5 control until a 1200 CPM reading is obtained.

5) Set the input signal frequency to 200 CPS. Set the "FREQUENCY RANGE" switch to 15. Adjust the FREQ. METER ADJ. 15 control until a 12,000 CPM reading is obtained.

6-5 Calibration of the Tunable Filter - The FILTER ADJUST controls should be checked for proper adjustment when either the tubes in the filter circuits are replaced or whenever the IN and OUT "AMPLITUDE" meter readings differ appreciably with a sine wave input to the instrument. To adjust the filter circuits for proper operation, proceed as follows:

1) Calibrate the amplitude circuit if it has not been calibrated previously as outlined in Sec. 6-3, Steps 1 through 4.

2) Set the "AMPLITUDE-MILS" switch to 1 mil position, the "FILTER-OSC. SELECTOR" Switch to OUT, the "FREQUENCY RANGE" switch to position .5K and the "DAMPING" switch to "HI".

3) Apply a 7 CPS signal to the INPUT CONNECTOR and adjust the signal amplitude to obtain .9 of full-scale meter reading.

4) Switch the "FILTER-OSC. SELECTOR" switch to IN and slowly turn the "FILTER-OSC. TUNING" dial to 420 CPM while watching the "AMPLITUDE" meter. The meter will peak at 420 CPM and should

read .9 of full scale as was the case with the OUT position. If the IN and the OUT readings are not the same, adjust the "FILTER ADJUST" .5K control until the two readings are identical. While setting the FILTER ADJUST controls, always rock the "FILTER-OSC. TUNING" knob back and forth to insure an accurate peak tuning adjustment.

5) Turn the "FREQUENCY RANGE" switch to 1.5 and apply a 20 CPS input signal. Adjust the signal generator amplitude until the AMPLITUDE meter reads approximately .9 of full scale. Switch to filter IN. Tune the "FILTER-OSC. TUNING" control to this frequency. No change in the AMPLITUDE METER reading should be observed when switching from OUT to IN. If a change is noted in the IN position, adjust the FILTER ADJUST 1.5K control until the OUT and IN readings are identical. Rock the "FILTER-OSC TUNING" knob back and forth to insure an accurate tuning adjustment.

6) Turn the "FREQUENCY RANGE" switch to the 5K position and apply a 70 CPS input signal and repeat as in Step 5 for 20 CPS. Switch "FILTER-OSC. SELECTOR" switch to IN. Tune the "FILTER-OSC. TUNING" control to this frequency (70 CPS). No change should be noted when switching from IN to OUT. If a change is noted for the IN position, adjust the FILTER ADJUST 5K control until the OUT and IN readings are identical.

7) Repeat Step 5 using a frequency of 200 CPS for the 15K frequency range. Adjust the 15K "FILTER ADJUST" control, if necessary.

6-6 Pickup Calibration - Two methods may be used to calibrate the Model 601 for use with a particular pickup.

1) The first of these methods involves the use of an audio signal generator which is adjusted to give a signal output equal to the pickup signal at a given frequency and load. This signal is then applied to the input of the instrument and the AMP. GAIN control adjusted to read the displacement, double-amplitude, corresponding to that pickup signal output. This method has the disadvantage of reduced accuracy of amplitude indication if several pickups, not all having the same signal output at given displacements and frequencies, are the same signal output at given displacements and frequencies, are to be used with the instrument. On the other hand, this method affords a rapid pickup-and instrument-check and, in many applications, will be found useful.

Before calibration may be made with a pickup, the pickup sensitivity must be known. This sensitivity must be in MVRMS/100 CPS/.001 INCH P-P. If the sensitivity is in MVRMS/INCH/SEC., conversion may be made to the required as follows:

$$e_o = \frac{K \pi fA}{1.41}$$

Where:

e_o = MVRMS/100 CPS/.001 INCH P-P
K = MVRMS/INCH.SEC.
f = 100 CPS
A = .001 INCH. P-P
π = 3.14

The signal output of the IRD Model 544 Vibration Pickup, which is the pickup normally supplied with the Model 601 is: 240 MVRMS ± 5% per .001 inch peak-to-peak displacement at 100 CPS.

6-7 The procedure for calibrating the Model 601 with a velocity type pickup is as follows:

1) Connect oscillator to the input connector. Use an AN3106B 10 SL 4S connector and a shielded cable from oscillator.

2) Connect the VTVM to the oscillator terminals.

3) Turn equipment ON and allow a 15 minute minimum warmup time.

4) Make the following settings on the Model 601:

a) "FILTER-OSC. SELECTOR" in OUT position.

b) "AMPLITUDE-MILS" switch in the 1 mil position.

c) "FREQUENCY RANGE" in the 15 position.

d) "DAMPING" switch in LO.

5) Adjust oscillator frequency as read on the oscillator dial and output as read on the VTVM to the MVRMS at 100 CPS at .001 inch P-P for the PICKUP to be used with the ANALYZER. MAKE THIS ADJUSTMENT WITH CARE.

6) Adjust the AMP. GAIN control until the AMPLITUDE METER reads 1 mil full scale. Lock GAIN CONTROL pot. This calibrates the Model 601 for use with this pickup.

2) The second method of amplitude calibration is by use of an accurately calibrated shaker system where the pickup is subjected to known displacements and the GAIN control can be adjusted to give the proper AMPLITUDE METER reading. This method has the advantage of superior accuracy, but, at times, inconvenient if an accurate shaker system is not readily available.

6-8 Test Signal Adjustment - The test signal is used as a self-check feature of the instrument. The test signal is obtained by clipping a large 60 CPS sine wave and using a small portion of the clipped wave as a test signal feeding into the INPUT of the instrument. The test signal of all the calibration adjustments is adjusted last, and is done as follows:

1) Set the "AMPLITUDE-MILS" switch to TEST. Set the "FREQUENCY RANGE" switch to 5K RPM.

2) The TEST SIGNAL ADJUST should be adjusted to read 1/2 scale on the "AMPLITUDE" meter.

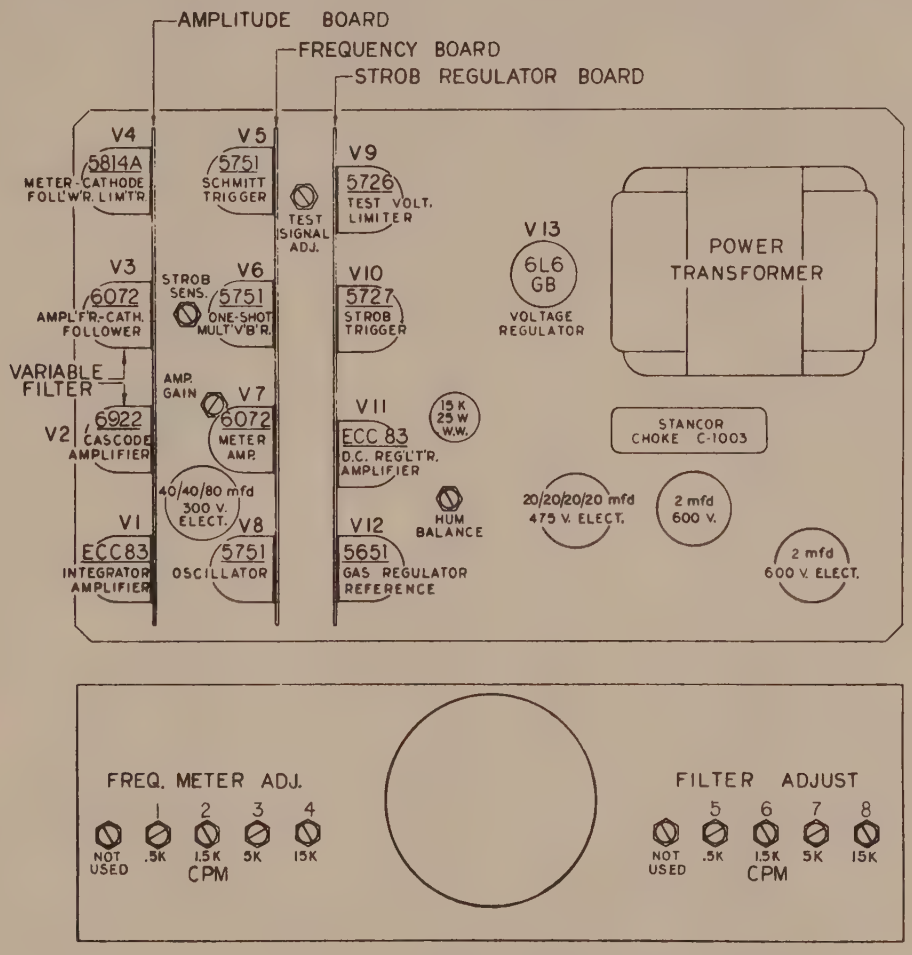
NOTE

Whenever the AMP. GAIN control is readjusted the TEST SIGNAL ADJUST should be recalibrated also. This control is dependent on the AMPLITUDE GAIN adjustment.

7 - SPARE PARTS LIST

The following is an itemized listing of the parts which most probably are subject to field replacement. For that reason, they comprise the recommended spare parts list for general service of the instrument.

Part Description	IRD Part Number	Manufacturer
Power Cord	1065-11-8-A	
Grounding Extension Plug	600-90-12-A	
Pointer Knob (Gray)		Raytheon #70-5-2G
Round Knob (Gray) Large		Raytheon #125-212G
Tuning Dial Glass	600-36-A	
Amplitude Meter 4 1/2 inch Lighted, Custom Chrome IMA Meter	600-8 Face	Phaostron
Frequency Meter 4 1/2 inch Lighted, Custom Chrome IMA Meter	600-9 Face	Phaostron
Tube 5814A		General Electric
Tube 6072		General Electric
Tube ECC83		Amperex
Tube 5651		General Electric
Tube 5726		General Electric
Tube 5727		General Electric
Tube 5751		General Electric
Tube 6L6GB		General Electric
Silicon Rectifier (Four)		Sarkes Tarzian 80SM or International Rectifier #5095
Dial Lamp		General Electric #47
Dial Lamp (Meters)		Dialco #7-06
Tube Shield 1-15/16 in.		Cinch Jones 9S2
Spring, Dial, Drive Type 3		Walsco Electronics Manufacturing Co.
Fuse Extractor, Miniature 3AG		Littlefuse
Cable, Dial, Phospher-Bronze (30 1/2 in. long)		Walsco Electronics Manufacturing Co.
		Littlefuse
		Walsco Electronics Manufacturing Co.
Tube 6922		Amperex



TUBE LAYOUT - MODEL 601

INTERNATIONAL RESEARCH AND DEVELOPMENT CORPORATION, COLUMBUS OHIO	DRAWING REVISION	LTR	DATE
	DO NOT SCALE	DR BY R. Davidson	7/21/
MATERIAL / FINISH		CH BY Red Garrigus	7/21/
		APP BY W. Thomas	7/21/
DRAWING TITLE		NEXT ASSY.	DRAWING NO
			601-4
TOLERANCES: UNLESS SPECIFIED FRACTIONS 1/64 DECIMALS 0.005 ANGLES 1°		PRINT DATE	

CIRCUIT SYMBOL	DESCRIPTION	CIRCUIT SYMBOL	DESCRIPTION
Resistors – Unless otherwise specified, all fixed composition resistors are 1/2W, Tolerance ±5%.			
R1	1 Meg.		
R2	220K	R46	10K
R3	1.5K	R47	91K
R4	1 Meg.	R48	910K±1%, carbon film
R5	1.5K	R49	330K±1%, carbon film
R6	33K	R50	68K
R7	220K	R51	33K±1%, carbon film
R8	3.6 Meg., ±1%, carbon film	R52	1.8 Meg.
R9	750K±1%, carbon film	R53	33K
R10	120K	R54	1 Meg.
R11	10K	R55	6.8K
R12	3.3K	R56	120K
R13	1 Meg.	R57	2 Meg.
R14	330K 2W	R58	470K
R15	1 Meg. ±1%, carbon film	R59	22K
R16	8.2K	R60	82K, 1W
R17	820 ohm	R61	100 ohm
R18	220K	R62	4.7K
R19	1 Meg.	R63	1 Meg.
R20	1.2K	R64	470K
R21	22K	R65	1500 ohm
R22	82K	R66	1200 ohm
R22A	150K	R67	47K ohm, 1W
R23	150K	R68	33K
R24	2.2 Meg.	R69	1K
R25	330K	R71	2K Freq. Adj. Miniature Potentiometers
R26	1.5K	R72	
R27	68K±1%, carbon film	R73	
R28	22K±1%, carbon film	R74	
R29	6.8K±1%, carbon film	R75	470 ohm
R30	2.2K±1%, carbon film	R76	6.8K
R31	680±1%, carbon film	R77	6.8K
R32	220±1%, carbon film	R78	1K
R33	100, ±1%, carbon film	R79	6.8K
R35	15K Potentiometer	R80	6.8K
R36	1K Potentiometer	R81	100K
R37	360K±1%, carbon film	R82	1M
R38	2.2 Meg.	R83	6.8K
R39	0.5 Meg. Potentiometer	R84	68K, 1W
R40	4.7 Meg.	R85	330K
R41	330K	R86	15K, 25W
R42	3.3 Meg.	R87	1M
R43	82K	R88	1M
R44	750K	R89	8.2K
R45	620K	R90	8.2K

CIRCUIT SYMBOL	DESCRIPTION
R91	2 Meg.±1%, carbon film
R92	68K
R93	68K, 2W
R94	3.3M
R95	33K±1%, carbon film
*R96	100K,WW Potentiometer
*R97	100K,WW Potentiometer
R98	33K±1%
R99	3.3K
*R100	50K,WW Potentiometer
R102	20K, Min. Potentiometers
R103	20K, Min. Potentiometers
R104	20K, Min. Potentiometers
R105	20K, Min. Potentiometers
R106	330K
R107	27K
R108	150-2W
R109	100K
R110	68K
R111	91K
R112	68K-1W
R113	100 ohm Potentiometer
R114	12K±1%, carbon film
R115	10K±1%, carbon film

*3 Gang Potentiometer

Capacitors - Unless otherwise specified, all capacitors are 200 VDC

C1	.15 mf, Paper
C2	.25 mf, Paper
C3	.01 mf, 500V Mica
C4	500 mf-6V Electrolytic
C5	.25 mf, Mylar
C6	.22 mf, Paper
C7	50 mmf MICA 500 VDC
C8	.68 mf, Mylar
C10	40 mf-300 VDC Electrolytic
C11	40 mf-300 VDC Electrolytic
C12	0.22 mf, Mylar
C13	5mmf Mica, 500 VDC
C14	50 mmf Mica, 500 VDC
C16	.0024 mfd Values in Capacitor Assembly #651-33. All Values ±2-1/2%
C17	.0078 mfd Values in Capacitor Assembly #651-33. All Values ±2-1/2%
C18	.024 mfd Values in Capacitor Assembly #651-33. All Values ±2-1/2%
C19	.078 mfd Values in Capacitor Assembly #651-33. All Values ±2-1/2%

CIRCUIT SYMBOL	DESCRIPTION
C20	0.1 mf 400 VDC, Mylar
C21	.22 mf, Mylar
C21A	100 mf 250 VDC
C21B	100 mf 250 VDC
C22	80 mf 300 VDC, Electrolytic
C23	.22 mf, Mylar
C23A	1000 mf-6V Electrolytic
C24	150 mf-50V Electrolytic
C25	20 mf 150V Electrolytic
C26	250 mf 25V Electrolytic
C27	1000 mf 6V Electrolytic
C28	.0047 mf 400 VDC, Mylar
C29	.047 mf 400 VDC, Mylar
C30	20 mf 475V Electrolytic
C31	.001 mfd Mica 500 VDC
C32	100 mf 12 VDC Electrolytic
C33	2 mf-600 VDC
C34	20 mf 475 VDC Electrolytic
C35	20 mf 475 VDC Electrolytic
C36	20 mf 475 VDC Electrolytic
C37	2 mf 600 VDC Oil
C39	.0330 mfd±0-2% Capacitor Assembly #651-32 200 VDC
C40	.0994 mfd±0-2% Capacitor Assembly #651-32 200 VDC
C41	.3310 mfd±0-2% Capacitor Assembly #651-32 200 VDC
C42	.9940 mfd±0-2% Capacitor Assembly #651-32 200 VDC
C43	.4970 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C44	.1655 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C45	.0497 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C46	.0155 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C49	.0155 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C50	.0497 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C51	.1655 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C52	.4970 mfd±2-0% Capacitor Assembly #651-32 200 VDC
C53	.22 mf, Mylar
C54	.25 mf-600 VDC, Paper
C55	0.1 mf-400 VDC, Paper
C56	.047 mf-400 VDC, Mylar
C57	.1 mf-400 VDC, Mylar

Tubes - Unless otherwise specified, all tubes are General Electric Five Star or equivalent.

V1	ECC83-Amperex
V2	6922
V3	6072 GE on PCB
V4	5814A #651-26

CIRCUIT SYMBOL	DESCRIPTION
V5	5751
V6	5751 onPCB #600-15
V7	6072
V8	5751
V9	5726
V10	5727 on PCB
V11	ECC83-Amperex #600-14
V12	5651
V13	6L6-GB (Power tube on #600-69 Baseboard)

Miscellaneous

Dial Lights (2) - GE #47

Fuses (2) - 1 - 1/2 AMP. Slo Blo 3
AG 1 Littelfuse

Strob Con. - (1) Deutch M8501-14S-4S

DC Recorder - (1) Amphenol #80-PCZF

Scope Jack (1) Amphenol #80C

Meters - (2) Phaostron 4x6 Custom
0 - 1 DC Milliampere
A - (1) Amplitude = #600-8 Meterface
B - (1) Frequency = #600-9 Meterface

110 VAC - (1) outlet - Amphenol #61F
(1) inlet - Hubbell #7486

Pickup Connector (1) Amphenol MS3102A-10SL-4P

Fuse Holder (2) Littelfuse #342003

D1 International 3AS1
D2 International 3AS1
D3 Raytheon IN305
D4 Raytheon IN305
D5 Sarkes Tarzian 80SM or Diodes Inc. DI510
D6 Sarkes Tarzian 80SM or Diodes Inc. DI510
D7 Sarkes Tarzian 80SM or Diodes Inc. DI510
D8 Sarkes Tarzian 80SM or Diodes Inc. DI510

CIRCUIT SYMBOL	DESCRIPTION
D9	Raytheon IN67
D10	Raytheon IN67
D11	Raytheon IN67
D12	Raytheon IN67
K1	SPDT 10K ohm 100 MW RELAY "Line Electric Co."
T1	Power Transformer (IRD #600-105)
CH1	16 HY-50MA

Ruggedized/Standard-Tube Substitution Chart

Ruggedized	Standard
5726	6AL5
5727	2D21
5751	12AX7
5814A	12AU7
6072	12AY7

Tubes not listed do not have a direct standard substitute replacement.
For emergency replacement only use:
ECC83 12AX7 or 5751